Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1. (currently amended) A method of constructing a virtual three-dimensional model of an object from a scanner, a data processing system, and at least one machine-readable memory accessible to said data processing system, comprising the steps of:

(a) scanning the object with the scanner and thereby obtaining at least two two-dimensional images of the object, wherein during scanning the scanner and object are moved relative to each other resulting in each image being taken from a different position relative to the surface of the object;

(b) processing said data representing said set of images with said data processing system so as to convert each of said two-dimensional images into [[a]] data representing a frame and thereby generate a set of frames corresponding to said images, said set of frames comprising a cloud of individual points, each point in each frame expressed as a location in a three-dimensional X, Y, and Z coordinate system;

(c) storing data representing said set of frames in said memory; and

(d) further processing said data representing said set of frames with said data processing system so as to register said frames relative to each other using a frame to frame registration process to thereby produce a three-dimensional virtual model of the object substantially consistent with all of said frames[[.]]; said frame to farme registration process comprising the steps of:

(i) performing an initialization step comprising the sub-steps of:

(A) selecting one of the frames from said set of frames as the first frame;

(B) ordering said set of frames in a sequence of frames $Frame_i$ for i = 1 to N for further processing, wherein $Frame_1$ is the first frame;

(C) setting a quality index for evaluating the quality of the overall registration of one frame to another frame;

(D) setting the frame subscript value i = 2; and

(E) selecting $Frame_{i-1}$ and $Frame_i$ for registering $Frame_i$ to $Frame_{i-1}$;

(ii) transforming the Z coordinate of every point in $Frame_i$, thereby bringing $Frame_i$ closer to $Frame_{i-1}$, comprising the sub-steps of:

(A) calculating for $Frame_{i-1}$: (1) the sum of all Z coordinates $Z_{sum\ i-1}$ = sum of the Z coordinate of every point in $Frame_{i-1}$; and (2) the median Z coordinate $Z_{median\ i-1} = Z_{sum\ i-1}$ divided by the number of points in $Frame_{i-1}$;

(B) calculating for $Frame_i$: (1) the sum of all Z coordinates $Z_{sum\ i}$ = sum of the Z coordinate of every point in $Frame_i$; and (2) the median Z coordinate $Z_{median\ i} = Z_{sum\ i}$ divided by the number of points in $Frame_i$; and

(C) calculating $\Delta Z = Z_{median\ i} - Z_{median\ i-1}$; subtracting ΔZ from the Z coordinate of every point in $Frame_i$, thereby transforming the Z coordinate

of every point in $Frame_i$, and setting $Frame_i$ = $Frame_i$ having the transformed Z coordinates.

(iii) calculating the translation matrix for $Frame_i$ comprising the sub-steps of:

(A) calculating a minimum distance vector from every point in $Frame_i$ to the surface of $Frame_{i-1}$, thereby creating a set of minimum distance vectors for $Frame_i$;

(B) eliminating from said set of minimum distance vectors for $Frame_i$ each of said set of minimum distance vector for $Frame_i$ that satisfies one or more exclusion criteria from a set of exclusion criteria, thereby creating a remaining set of minimum distance vectors for $Frame_i$, and marking each of the points corresponding to the remaining set of minimum distance vectors for $Frame_i$ as an overlapping point, wherein said overlapping points define the area of overlap between $Frame_{i-1}$ and $Frame_i$;

(C) calculating a vector sum of minimum distance vectors for $Frame_i$ by summing all minimum distance vectors corresponding to said overlapping points in $Frame_i$; and

(D) calculating a median minimal distance vector $(t)_i$ for $Frame_i$ by dividing the vector sum of minimum distance vectors for $Frame_i$ with the number of vectors corresponding to said overlapping points in $Frame_i$

thereby the median minimal distance vector $(t)_i$ for $Frame_i$ forming the translation matrix $[T](t)_i$;

(iv) calculating the rotation transformation matrix for $Frame_i$ comprising the sub-steps of:

(A) creating a copy of $Frame_i$, and designating said copy of $Frame_i$ $Frame_{i*}$;

(B) subtracting the median minimal distance vector $(t)_i$ from every point in $Frame_{i*}$;

(C) gettng a position vector for every overlapping point in $Frame_{i*}$ extending from the origin of the coordinate system for $Frame_{i*}$ to the overlapping point in $Frame_{i*}$;

(D) calculating a vector sum of all position vectors corresponding to all of the overlapping points in $Frame_{i*}$;

(E) calculating the center of mass for $Frame_{i*}$ by dividing the vector sum of all position vectors corresponding to all of the overlapping points in $Frame_{i*}$ with the number of said position vectors corresponding to all of said overlapping points in $Frame_{i*}$;

(F) calculating a cross-vector for every overlapping point in $Frame_{i*}$ by performing a cross-product operation of (1) the position vector for the overlapping point in $Frame_{i*}$ substracted by the vector of the center

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of mass for $Frame_{i*}$ and (2) said minimum distance vector for the overlapping point in $Frame_{i*}$;

(G) calculating a sum of all the cross-vectors corresponding to all of the overlapping points in $Frame_{i*}$;

(H) applying a weighting factor to the sum of all of said cross-vectors for $Frame_{i*}$ thereby producing a weighted sum of all the cross-vectors for $Frame_{i*}$; and

(I) scaling the weighted sum of all the cross-vectors for $Frame_{i*}$ with an empirical acceleration factor f thereby creating a scaled weighted sum of all the cross-vectors for $Frame_{i*}$ thereby said scaled weighted sum of all the cross-vectors for $Frame_{i*}$ forming the rotation transformation matrix $[T](R)_i$.

(v) applying the transformation to $Frame_i$ and evaluating the results comprising the sub-steps of:

(A) computing the transformation matrix for $Frame_i$ $[T]_i = + [T](t)_i + [T](R)_i$; and applying the transformation matrix $[T]_i$ to every point in $Frame_i$ thereby producing a transformed $Frame_i$ wherein $[T](t)_i$ produces the transalation of the X, Y and Z coordinates of every point in $Frame_i$ and $[T](R)_i$ produces the magnitude and direction of rotation of $Frame_i$;

(B) calculating the closeness factor of the transformed Frame_i and Frame_{i-1} and comparing said closeness factor with the quality index;

(C) if the closeness factor > the quality index, then returning to step (iii); otherwise proceeding to the next step;

(D) if $i < N$, setting $i = i + 1$ and returning to step (ii) until Frame_N is registered.

Claim 2. (canceled)

Claim 3. (currently amended) The method of claim 1, wherein step (d) further comprises the step of performing a cumulative registration of said set of frames., ~~wherein at least some of said frames are registered to a plurality of other frames previously having been registered to other frames in said set of frames.~~

Claim 4. (canceled)

Claim 5. (currently amended) The method of claim 1, wherein in step (d)(i) ~~one of~~ after selecting said ~~frames is a~~ starting frame for registration, ~~and wherein~~ a spatial transformation relationship is derived for each of the other frames in said set of frames and stored in said memory, said spatial transformation relationship indicating how the points in said frame should be translated and rotated in a three-dimensional coordinate system to register said frames relative to said starting frame.

Claim 6. (currently amended) The method of claim [[5]]1, wherein said starting frame corresponds to the first image captured by said scanner.

Claim 7. (currently amended) The method of claim [[5]]1, wherein said starting frame corresponds to selected image taken of the object and in which other images were taken of the object in the same vicinity of the object such that a substantial amount of overlap exists between said selected image and said other images.

Claim 8. (currently amended) The method of claim 1, wherein, in step (d), said ~~set of frames are registered to each other in a~~ sequential order ~~with the order~~ is determined, at least in part, upon the degree of overlap in coverage of said object in said frames.

Claim 9. (original) The method of claim 1, wherein said scanner comprises a hand-held scanning device and said object is scanned by moving said hand-held scanning device over said object.

Claim 10. (original) The method of claim 9, wherein said object comprises a human.

Claim 11. (original) the method of claim 10, wherein said object comprises teeth and associated anatomical structures.

Claim 12. (original) The method of claim 9, wherein said object comprises a model of an anatomical structure of a human.

Claim 13. (original) The method of claim 1, wherein said data processing system is incorporated into a work station for said scanner.

Claim 14. (original) The method of claim 1, wherein said data processing system comprises a general purpose computer operatively connected to said scanner and said memory.

Claim 15. (original) The method of claim 1, wherein said data processing system comprises at least two independent processors sharing the processing required by steps (c) and (d).

Claim 16. (original) The method of claim 15, wherein one of said processors is incorporated into a work station for said scanner and wherein the other processors comprises a computer remote from said work station.

Claim 17. (original) The method of claim 16, wherein said object comprises teeth and associated anatomical structures, and wherein said work station and scanner are located in an orthodontic clinic, and wherein said computer remote from said work station comprises a computer in said orthodontic clinic.

Claim 18. (original) The method of claim 1, wherein said scanner, said memory and said data processing system are housed in a single unit.

Claim 19. (original) The method of claim 1, wherein said data processing system is coupled to a user interface including a display, and wherein data processing system is operative to display said virtual three dimensional model on said display.

Claims 20-32. (canceled)

Claim 33. (currently amended) A method of creating a virtual three-dimensional object, comprising the steps of:

a) scanning said object in a series of scans, each scan generating a set of images;

b) converting said set of images into a set of three-dimensional frames;

c) registering said frames in each of said series of scans to each other <u>using a frame to frame registration process</u> to thereby generate a series of segments, each segment comprising a portion of a three-dimensional model of the object; <u>said frame to frame registration process comprising the steps of:</u>

<u>(i) performing an initialization step comprising the sub-steps of:</u>

<u>(A) selecting one of the frames from said set of frames as the first frame;</u>

(B) ordering said set of frames in a sequence of frames $Frame_i$ for i = 1 to N for further processing, wherein $Frame_1$ is the first frame;

(C) setting a quality index for evaluating the quality of the overall registration of one frame to another frame;

(D) setting the frame subscript value i = 2; and

(E) selecting $Frame_{i-1}$ and $Frame_i$ for registering $Frame_i$ to $Frame_{i-1}$;

(ii) transforming the Z coordinate of every point in $Frame_i$, thereby bringing $Frame_i$ closer to $Frame_{i-1}$, comprising the sub-steps of:

(A) calculating for $Frame_{i-1}$: (1) the sum of all Z coordinates $Z_{sum\ i-1}$ = sum of the Z coordinate of every point in $Frame_{i-1}$; and (2) the median Z coordinate $Z_{median\ i-1} = Z_{sum\ i-1}$ divided by the number of points in $Frame_{i-1}$;

(B) calculating for $Frame_i$: (1) the sum of all Z coordinates $Z_{sum\ i}$ = sum of the Z coordinate of every point in $Frame_i$; and (2) the median Z coordinate $Z_{median\ i} = Z_{sum\ i}$ divided by the number of points in $Frame_i$; and

(C) calculating $\Delta Z = Z_{median\ i} - Z_{median\ i-1}$; subtracting ΔZ from the Z coordinate of every point in $Frame_i$, thereby transforming the Z coordinate of every point in $Frame_i$, and setting $Frame_i$ = $Frame_i$ having the transformed Z coordinates.

(iii) calculating the translation matrix for Frame_i comprising the sub-steps of:

(A) calculating a minimum distance vector from every point in Frame_i to the surface of Frame_{i-1}, thereby creating a set of minimum distance vectors for Frame_i;

(B) eliminating from said set of minimum distance vectors for Frame_i each of said set of minimum distance vector for Frame_i that satisfies one or more exclusion criteria from a set of exclusion criteria, thereby creating a remaining set of minimum distance vectors for Frame_i, and marking each of the points corresponding to the remaining set of minimum distance vectors for Frame_i as an overlapping point, wherein said overlapping points define the area of overlap between Frame_{i-1} and Frame_i;

(C) calculating a vector sum of minimum distance vectors for Frame_i by summing all minimum distance vectors corresponding to said overlapping points in Frame_i; and

(D) calculating a median minimal distance vector $(t)_i$ for Frame_i by dividing the vector sum of minimum distance vectors for Frame_i with the number of vectors corresponding to said overlapping points in Frame_i thereby the median minimal distance vector $(t)_i$ for Frame_i forming the translation matrix $[T](t)_i$;

(iv) calculating the rotation transformation matrix for Frame_i comprising the sub-steps of:

(A) creating a copy of Frame_i, and designating said copy of Frame_i Frame_{i^*};

(B) subtracting the median minimal distance vector $(t)_i$ from every point in Frame_{i^*};

(C) gettng a position vector for every overlapping point in Frame_{i^*} extending from the origin of the coordinate system for Frame_{i^*} to the overlapping point in Frame_{i^*};

(D) calculating a vector sum of all position vectors corresponding to all of the overlapping points in Frame_{i^*};

(E) calculating the center of mass for Frame_{i^*} by dividing the vector sum of all position vectors corresponding to all of the overlapping points in Frame_{i^*} with the number of said position vectors corresponding to all of said overlapping points in Frame_{i^*};

(F) calculating a cross-vector for every overlapping point in Frame_{i^*} by performing a cross-product operation of (1) the position vector for the overlapping point in Frame_{i^*} substracted by the vector of the center of mass for Frame_{i^*} and (2) said minimum distance vector for the overlapping point in Frame_{i^*};

(G) calculating a sum of all the cross-vectors corresponding to all of the overlapping points in Frame_{i^*};

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(H) applying a weighting factor to the sum of all of said cross-vectors for $Frame_{i*}$ thereby producing a weighted sum of all the cross-vectors for $Frame_{i*}$; and

(I) scaling the weighted sum of all the cross-vectors for $Frame_{i*}$ with an empirical acceleration factor f thereby creating a scaled weighted sum of all the cross-vectors for $Frame_{i*}$ thereby said scaled weighted sum of all the cross-vectors for $Frame_{i*}$ forming the rotation transformation matrix $[T](R)_i$.

(v) applying the transformation to $Frame_i$ and evaluating the results comprising the sub-steps of:

(A) computing the transformation matrix for $Frame_i$ $[T]_i = + [T](t)_i + [T](R)_i$; and applying the transformation matrix $[T]_i$ to every point in $Frame_i$ thereby producing a transformed $Frame_i$ wherein $[T](t)_i$ produces the transalation of the X, Y and Z coordinates of every point in $Frame_i$ and $[T](R)_i$ produces the magnitude and direction of rotation of $Frame_i$;

(B) calculating the closeness factor of the transformed $Frame_i$ and $Frame_{i-1}$ and comparing said closeness factor with the quality index;

(C) if the closeness factor > the quality index, then returning to step (iii); otherwise proceeding to the next step;

(D) if $i < N$, setting $i = i + 1$ and returning to step (ii) until $Frame_N$ is registered;

and

d) registering said segments relative to each other to thereby create said virtual three-dimensional model.

Claim 34. (original) The method of claim 33, wherein step d) comprises the steps of:

1. displaying on a monitor each of said segments,
2. prompting a user to select with a user interface device a location on each of said segments which overlaps at least one other segment;
3. storing said locations selected by said user; and
4. using said stored locations as a starting point for registering said segments relative to each other.

Claim 35. (original) The method of claim 34, further comprising the step of displaying on said monitor the virtual three-dimensional model.

Claim 36. (original) The method of claim 33, further comprising the step of performing a cumulative registration of all of said frames forming said virtual three-dimensional model.

Claim 37. (original) The method of claim 34, wherein said object comprises teeth and wherein said locations selected by the user in step 2. comprise locations where virtual brackets are placed on teeth in an orthodontic treatment planning for said teeth.

Claim 38. (original) The method of claim 37, wherein said locations are represented on said display by a graphical icon.

Claim 39. (original) The method of claim 38, wherein said icon appears as a virtual three-dimensional object.

Claim 40. (original)The method of claim 39, wherein said virtual three-dimensional object comprises a circular portion having a center located on the location selected by the user and direction indicating portion.

Claim 41. (original) An orthodontic workstation performing steps b, c) and d) of the method of claim 33.

Claim 42. (original) The method of claim 33, wherein said step of scanning is performed with a hand-held scanner.

Claim 43. (currently amended) A method of constructing a virtual three-dimensional model of an object using a data processing system, and at least one

machine-readable memory accessible to said data processing system, comprising the steps of:

(a) obtaining a set of at least two digital three-dimensional frames of portions of the object, wherein said at least two frames comprise a set of point coordinates in a three dimensional coordinate system providing differing information of the surface of said object, whereas those frames provide a substantial overlap of the represented portions of the surface of the said object;

(b) storing data representing said set of frames in said memory; and

(c) processing said data representing said set of frames with said data processing system so as to register said frames relative to each other using a frame to frame registration process to thereby produce a three-dimensional virtual representation of the portion of the surface of said object covered by said set of frames, without using pre-knowledge about the spatial relationship between said frames; said three-dimensional virtual representation being substantially consistent with all of said frames[[.]]; said frame to frame registration process comprising the steps of:

(i) performing an initialization step comprising the sub-steps of:

(A) selecting one of the frames from said set of frames as the first frame;

(B) ordering said set of frames in a sequence of frames $Frame_i$ for i = 1 to N for further processing, wherein $Frame_1$ is the first frame;

(C) setting a quality index for evaluating the quality of the overall registration of one frame to another frame;

(D) setting the frame subscript value $i = 2$; and

(E) selecting $Frame_{i-1}$ and $Frame_i$ for registering $Frame_i$ to $Frame_{i-1}$;

(ii) transforming the Z coordinate of every point in $Frame_i$, thereby bringing $Frame_i$ closer to $Frame_{i-1}$, comprising the sub-steps of:

(A) calculating for $Frame_{i-1}$: (1) the sum of all Z coordinates $Z_{sum\ i-1}$ = sum of the Z coordinate of every point in $Frame_{i-1}$; and (2) the median Z coordinate $Z_{median\ i-1} = Z_{sum\ i-1}$ divided by the number of points in $Frame_{i-1}$;

(B) calculating for $Frame_i$: (1) the sum of all Z coordinates $Z_{sum\ i}$ = sum of the Z coordinate of every point in $Frame_i$; and (2) the median Z coordinate $Z_{median\ i} = Z_{sum\ i}$ divided by the number of points in $Frame_i$; and

(C) calculating $\Delta Z = Z_{median\ i} - Z_{median\ i-1}$; subtracting ΔZ from the Z coordinate of every point in $Frame_i$, thereby transforming the Z coordinate of every point in $Frame_i$, and setting $Frame_i$ = $Frame_i$ having the transformed Z coordinates.

(iii) calculating the translation matrix for $Frame_i$ comprising the sub-steps of:

(A) calculating a minimum distance vector from every point in $Frame_i$ to the surface of $Frame_{i-1}$, thereby creating a set of minimum distance vectors for $Frame_i$;

(B) eliminating from said set of minimum distance vectors for $Frame_i$ each of said set of minimum distance vector for $Frame_i$ that satisfies one or more exclusion criteria from a set of exclusion criteria, thereby creating a remaining set of minimum distance vectors for $Frame_i$, and marking each of the points corresponding to the remaining set of minimum distance vectors for $Frame_i$ as an overlapping point, wherein said overlapping points define the area of overlap between $Frame_{i-1}$ and $Frame_i$;

(C) calculating a vector sum of minimum distance vectors for $Frame_i$ by summing all minimum distance vectors corresponding to said overlapping points in $Frame_i$; and

(D) calculating a median minimal distance vector $(t)_i$ for $Frame_i$ by dividing the vector sum of minimum distance vectors for $Frame_i$ with the number of vectors corresponding to said overlapping points in $Frame_i$ thereby the median minimal distance vector $(t)_i$ for $Frame_i$ forming the translation matrix $[T](t)_i$;

(iv) calculating the rotation transformation matrix for $Frame_i$ comprising the sub-steps of:

(A) creating a copy of $Frame_i$, and designating said copy of $Frame_i$ $Frame_{i*}$;

(B) subtracting the median minimal distance vector $(t)_i$ from every point in $Frame_{i*}$;

(C) gettng a position vector for every overlapping point in $Frame_{i*}$ extending from the origin of the coordinate system for $Frame_{i*}$ to the overlapping point in $Frame_{i*}$;

(D) calculating a vector sum of all position vectors corresponding to all of the overlapping points in $Frame_{i*}$;

(E) calculating the center of mass for $Frame_{i*}$ by dividing the vector sum of all position vectors corresponding to all of the overlapping points in $Frame_{i*}$ with the number of said position vectors corresponding to all of said overlapping points in $Frame_{i*}$;

(F) calculating a cross-vector for every overlapping point in $Frame_{i*}$ by performing a cross-product operation of (1) the position vector for the overlapping point in $Frame_{i*}$ substracted by the vector of the center of mass for $Frame_{i*}$ and (2) said minimum distance vector for the overlapping point in $Frame_{i*}$;

(G) calculating a sum of all the cross-vectors corresponding to all of the overlapping points in $Frame_{i*}$;

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(H) applying a weighting factor to the sum of all of said cross-vectors for $Frame_{i*}$ thereby producing a weighted sum of all the cross-vectors for $Frame_{i*}$; and

(I) scaling the weighted sum of all the cross-vectors for $Frame_{i*}$ with an empirical acceleration factor f thereby creating a scaled weighted sum of all the cross-vectors for $Frame_{i*}$ thereby said scaled weighted sum of all the cross-vectors for $Frame_{i*}$ forming the rotation transformation matrix $[T](R)_i$.

(v) applying the transformation to $Frame_i$ and evaluating the results comprising the sub-steps of:

(A) computing the transformation matrix for $Frame_i$ $[T]_i = +[T](t)_i + [T](R)_i$; and applying the transformation matrix $[T]_i$ to every point in $Frame_i$ thereby producing a transformed $Frame_i$ wherein $[T](t)_i$ produces the transalation of the X, Y and Z coordinates of every point in $Frame_i$ and $[T](R)_i$ produces the magnitude and direction of rotation of $Frame_i$;

(B) calculating the closeness factor of the transformed $Frame_i$ and $Frame_{i-1}$ and comparing said closeness factor with the quality index;

(C) if the closeness factor > the quality index, then returning to step (iii); otherwise proceeding to the next step;

(D) if $i < N$, setting $i = i + 1$ and returning to step (ii) until $Frame_N$ is registered.

Claim 44. (original) The method of claim 43, wherein said at least two digital three-dimensional frames are obtained from a CT scanner.

Claim 45. (original) The method of claim 43, wherein said at least two digital three-dimensional frames are obtained from a Magnetic Resonance Tomography (MRT) scanner.

Claim 46. (original) The method of claim 43, wherein said at least two digital three-dimensional frames are obtained from a processing of a at least two overlapping two-dimensional images containing three-dimensional information.

Claim 47. (canceled)

Claim 48. (currently amended) The method of claim 43, wherein step (c) further comprises the step of performing a cumulative registration of said set of frames.~~, wherein at least some of said frames are registered to a plurality of other frames previously having been registered to other frames in said set of frames.~~

Claim 49. (canceled)

Claim 50. (currently amended) The method of claim 43, wherein in step (c)(i) ~~one of~~ after selecting said ~~frames is a~~ starting frame for registration, ~~and wherein~~ a spatial transformation relationship is derived for each of the other frames in said set of frames and stored in said memory, said spatial transformation relationship indicating how the points in said frame should be translated and rotated in a three-dimensional coordinate system to register said frames relative to said starting frame.

Claim 51. (currently amended) The method of claim [[50]]43, wherein said starting frame corresponds to a first frame obtained of the object.

Claim 52. (currently amended) The method of claim [[50]]43, wherein said frames are derived from two-dimensional images of said object, and wherein said starting frame corresponds to a selected image taken of the object and in which other images were taken of the object in the same vicinity of the object such that a substantial amount of overlap exists between said selected image and said other images.

Claim 53. (currently amended) The method of claim 43, wherein, in step c) said ~~set of frames are registered to each other in a~~ sequential order ~~with the order~~ is determined, at least in part, upon the degree of overlap in coverage of said object in said frames.

Claim 54. (original) The method of claim 43, said set of frames are obtained from a scanning system having a scanner and wherein said scanner comprises a hand-held

scanning device and said object is scanned by moving said hand-held scanning device over said object.

Claim 55. (original) The method of claim 43, wherein said object comprises a human.

Claim 56. (original) The method of claim 55, wherein said object comprises teeth and associated anatomical structures.

Claim 57. (original) The method of claim 56, wherein said object comprises a model of an anatomical structure of a human.

Claim 58. (original) The method of claim 43, wherein said data processing system is incorporated into a work station for a scanner.

Claim 59. (original) The method of claim 43, wherein said data processing system comprises a general purpose computer operatively connected to a scanner and said memory.

Claim 60. (original) The method of claim 43, wherein said data processing system is coupled to a user interface including a display, and wherein data processing system is operative to display said virtual three dimensional model on said display.